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CENOZOIC HISTORY OF THE LARAMIE REGION, WYOMING[1]

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The region described in this paper centers in the city of Laramie in southeastern Wyoming. It is situated in the eastern edge of the Rocky Mountain province. Much has been written about its stratigraphy and structure, but less of its physiographic features and their origin. The latter I purpose to describe and interpret here, with such help as is afforded by the contemporaneous deposits. Some of the questions which arise may be decided even now with reasonable confidence, but others require the further study which will be given them in later years. Even on these doubtful points suggestions may be of value to those who pursue the future work.

Bed-rock geology.—The fundamental rocks of the district are granites, gneisses, and schists of pre-Cambrian age. Upon their deeply eroded surface rests a thick succession of unaltered sedimentary rocks which range from Pennsylvanian to late Cretaceous. Although some unconformities divide this series, it appears nevertheless to be a unit, structurally. Under the plains the strata are nearly flat. In the mountains they have been arched in unison and are now found dipping away at various angles from the axes of the anticlines. From the physiographic point of view the sedimentary sequence may be divided into two parts: the Carboniferous limestone and the younger beds chiefly of Permian and Mesozoic age. The limestone is the most resistant terrane of the district and its outcrops are usually marked by "hog-back" ridges. The shales and weak sandstones of the other divisions are exposed in the lowlands bordering the mountains.

Upon the eroded edges of the tilted Mesozoic and older rocks lies a third group of strata—the Tertiary and Pleistocene sediments. They are nearly horizontal and largely unconsolidated.

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Cretaceous sedimentation and orogeny.—If one may judge from the uniformity of the Cretaceous strata and the prevailing fineness of the materials of which they are composed, they were deposited upon a nearly level surface distant from any rugged highlands. Through much of the period this surface was beneath the sea, as shown by marine fossils; but toward the close it appears to have become a broad flat river-built plain[1] with marshes and lakes. It seems clear, then, that up to this time the Rocky Mountains were not in existence, and that the Mesozoic strata lay like a horizontal blanket over all of the Laramie district.

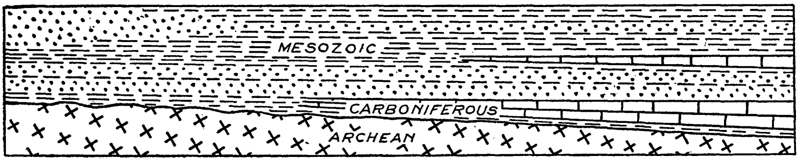

FIG. 1.—Probable condition of the Laramie district in late Cretaceous time.

The events of the initial Rocky Mountain disturbance are not satisfactorily recorded in the Laramie district. It has long been known, however, that at or near the close of the Cretaceous period the flat-lying strata of the Rocky Mountain province were wrinkled into their present attitudes, and locally were broken by faults. A distinctive negative feature of the Laramie region is the absence of the volcanic activity which, in many parts of the West, was a conspicuous accompaniment of this great disturbance.

Neglecting for the moment the effects of denudation, it may be said that these movements resulted in the formation of a low broad arch on the site of the present Laramie range, and a more irregular uplift, with local faults facing eastward, where the Medicine Bow ranges now stand.

Eocene erosion.—An immediate result of the mountain-building epoch must have been a period of active erosion of the rising arches. There is no reason to doubt that this accompanied the growth of the folds and carved them into rugged highlands from the very beginning of the uplift; but it also continued long after the structure of the ranges

[1] The interpretation advocated by Chamberlin and Salisbury (*Geology*, 1904, No. 111, p. 152) and others.

had been completed and static conditions reached. From the entire absence of exposures of Eocene sediments in southeast Wyoming, we may suspect that the chief activity of the region throughout the Eocene epoch was denudation. The abundance of pebbles of pre-Cambrian schists and granites in the basal gravel of the Oligocene series shows that the cover of stratified rocks had been entirely removed from the arches, and that the ancient rocks themselves were deeply eroded during the Eocene cycle. The folds were therefore truncated during Eocene time.[1]

Just what the final topographic result of this epoch of erosion was is now difficult to discern. There is some evidence, however, that it was not the complete planation of the district. Along the eastern border of the Laramie uplift the Oligocene deposits lie in valleys which had previously been cut through the limestone ridge. The intervening "hog-backs," which mark the outcrops of the Carboniferous limestone, stand 300–500 feet above these buried valleys. The relief just previous to the making of the Oligocene deposits must therefore have been at least as great in some parts of the district as that of the present.

On the other hand, the Oligocene deposits are notably fine and well stratified. They are not such formations as accumulate along the flanks of high mountains where streams have steep descents. From such facts as these it seems probable that by the close of the Eocene epoch the district in general was relatively low, but that the Laramie anticline was a hilly belt, while perhaps more rugged mountains were left farther west.

This uneven Eocene surface is preserved where it is still covered by the Oligocene strata, but over the rest of the area it seems to have been very largely destroyed by later cycles of erosion.

The Medicine Bow ranges west of the Laramie basin are essentially a maturely dissected plateau of schistose rocks with an average elevation of 10,000 feet. The plateau is topped by the rugged glaciated peaks locally called "the Snowy range," and by some lesser monadnocks. Farther east along the Laramie arch the nearly level top of Pole Mountain, at an elevation of 9,000 feet, may correspond in both origin and age to the Medicine Bow plateau. It rises high above the remarkably even surface later to be described as the Sherman peneplain. In the absence of more satisfactory evidence, I can only suggest as a plausible hypothesis, that this Medicine Bow plateau surface and Pole Mountain are remnants of the one developed by the Eocene cycle of denudation. When neighboring regions have been examined with these problems in mind the hypothesis may be either verified or cast aside.

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[1] Since this article went to press, my attention has been called by Mr. Bailey Willis to evidence indicating that the arches were partly uplifted in earlier Mesozoic times, and that the Paleozoic cover was removed from them before the Cretaceous sediments were laid down.

Mid-Tertiary sedimentation.—Reference has already been made to the Tertiary sediments which underlie the region east of the Sherman uplift. These consist largely of clays, soft sandstone, and conglomerate. As a rule the finer sediments are evenly stratified, and the colors are prevailingly light, being either white, gray, or yellow. The conglomerates are cross-bedded and locally indurated. It has been customary in the past to speak of these and similar deposits throughout the western mountain region as "lake beds," on the theory that fine stratified sediments could be deposited only in seas or in lake basins. More recently this origin has been called into question by Davis, Chamberlain, and others. It is now fairly well established that most of these Tertiary formations resemble those now being made by aggrading rivers, while some others bear a striking resemblance to eolian deposits. In the region under discussion it is highly probable that the Tertiary formations were deposited by streams in association with other terrestrial agencies, and the predominance of fine sediments indicates merely that the currents, whatever their nature, were of relatively weak transportive power.

The Oligocene beds resting on the eroded Eocene surface seem to imply that the erosive activities of the Eocene epoch were later subverted and gave way to aggradation. It is well, however, to bear in mind the alternative hypothesis that, without any marked change, a sheet of Piedmont alluvium which had been accumulating farther eastward during the Eocene epoch gradually spread westward as it was built higher and the highlands were reduced. In either case, the fact remains that the Eocene valleys were filled with clays and sands, and these sediments finally buried the lowland east of the Sherman uplift to a depth of several hundred feet. Embayments of this sheet of alluvium extend westward up into the valleys in the Sherman highlands, thus burying the outcrops of the upturned Carboniferous rocks, as already described. Even the divides between these valleys were more or less covered by the same deposits, for at Granite Canyon Tertiary beds are found lying on the top of one of these divides.

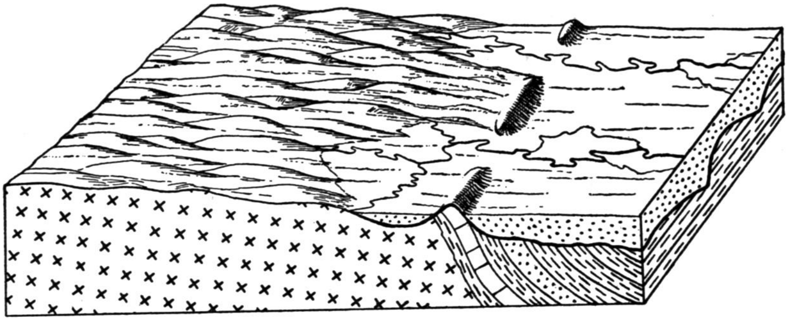

FIG. 2.—(Stereogram.) The Laramie uplift in the Oligocene epoch. The east flank partially buried by terrestrial deposits.

No trace of the middle Tertiary sediments has been found within the southern part of the Laramie basin. Just what the meaning of this fact may be is not now clear. While the Eocene surface (of which the Medicine Bow plateau is possibly a remnant) was being buried and thus preserved, east of the mountains, by the continued up-building of the Tertiary strata, corresponding denudation of the Sherman and Medicine Bow uplifts was probably in progress; but the record of it, if preserved, is too obscure to be read with any degree of confidence.

The exact age of the Tertiary sediments is a matter of considerable importance in working out the history of this region. According to Darton the lowest beds are the Chadron sands and the Brule clays, both of Oligocene age. These are followed by the conglomeratic Arikaree formation, which he assigns to early Miocene time. The close correlation of the Tertiary formations of the Great Plain is a matter of considerable difficulty, and perhaps the determinations thus far made should not be accepted too exactly. If, however, they are approximately right in this case, we may assign the epoch of alluviation to the Oligocene and early Miocene times.[1] This also gives us a convenient datum point to which we may refer some of the later events of the district.

Later Tertiary peneplain.—One of the most striking peculiarities of the Sherman uplift is its monotonous and relatively even surface. No imposing range of mountains, like that of the Uinta arch, marks its site. Roads run in almost every direction; and the Union Pacific Railroad crosses the divide, not through a deep pass, but across an open plateau. At the station of Sherman one may look for miles in almost any direction, and it is with difficulty that he realizes that his

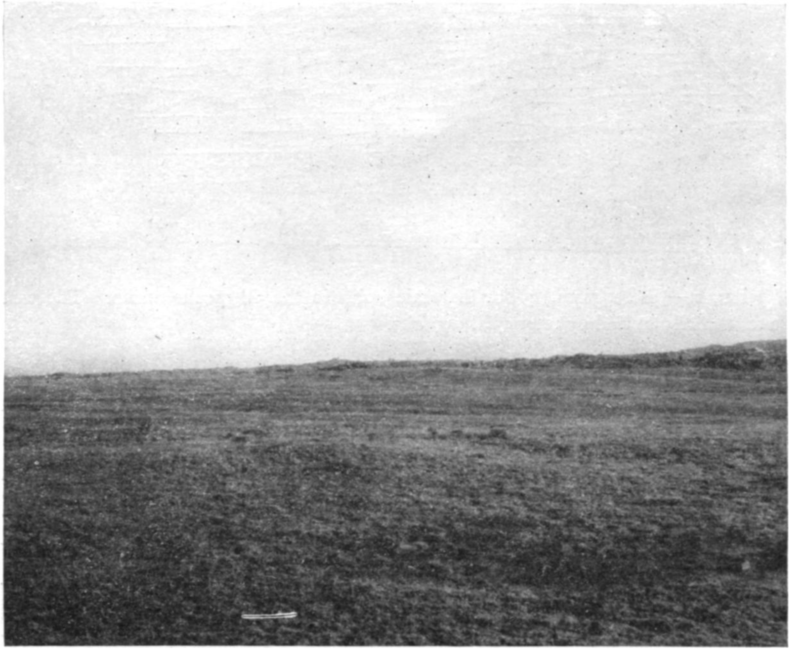

FIG. 3.—Subdued crest of the Laramie uplift, near Tie Siding. Undissected Sherman peneplain.

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[1] That this was not a time of constant conditions is indicated by the fact that the Arikaree is a coarse formation and lies unconformably on the finer sediments below. The significance of these facts has been commented on by Darton (*U. S. G. S. Professional Paper 32*, pp. 185, 186) and, as I am not in a position to add to his interpretation, they are passed over at this time.

viewpoint is 8,000 feet above sea-level, or as high as the summits of many of the rugged mountain ranges of the Northwest. When a closer examination is made, it is obvious to the geologist that the gently arched surface just described is in reality a plain of denudation, now more or less dissected. This surface passes with very little change across the outcrops of many different kinds of rocks. Schists, gneisses, porphyries, and gabbros are alike worn to a common level; and so slightly do they affect the details of the topography that surface forms are of doubtful value in mapping the outcrops of the different rock-formations. That the surface is a cut plain rather than a built plain is at once obvious, for outcrops of bed rock appear abundantly in it, although the majority of them are subdued and rounded, or even reduced to the level of the plain itself. In railroad cuts and in the open pits at Buford one may see that the granite and other rocks constitute all of the foundation, with scarcely any covering of soil or transported materials. The rocks are, however, deeply decayed, the granite being so soft that it is excavated with steam shovels to a depth sometimes exceeding 50 feet. In many exposures only the loose granitic gravel is to be seen, and by this alone the hasty observer might be misled. In these very exposures, however, one may often see quartz veins and small dikes, traversing the loose rubble right up to the grass-grown surface of the plateau. This shows that the material has not been disturbed. It is simply a thoroughly decayed mass of granite and other rocks.

It is, of course, not to be expected that this nearly level surface is a perfect plain. Here and there irregular knobs and piles of exfoliated bowlders rise above it, and a few hills or mountains of considerable size are scattered here and there over its surface. The highest of these are grouped in the Sherman Mountains, which have a maximum relief of nearly one thousand feet above the plain. These isolated elevations are doubtless monadnocks. Farther east, marking the outcrops of the hard Pennsylvanian limestone, there is a series of sharp hills or hog-backs which stand higher than the general surface of the Sherman peneplain. The coarse granite on the west and the soft sediments on the east are more easily eroded than the massive limestones.

The identification of the peneplain upon the Sherman uplift is a comparatively easy matter, because of the complexity of the rock structure beneath. Elsewhere difficulties are introduced. The high plateaus between the Sherman arch and the city of Cheyenne are seemingly an easterly continuation of the peneplain, for their tops

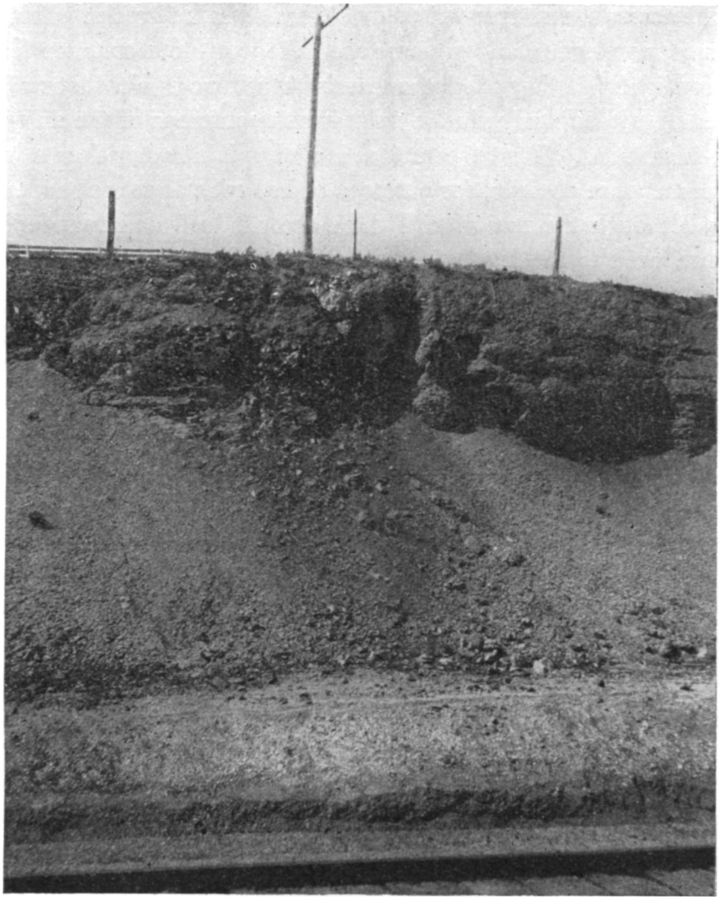

FIG. 4.—Decayed granite cut by a basic dike. A feature of the Sherman peneplain surface.

are at the proper elevation and do not seem to correspond exactly with the structure of the underlying rocks. However, the fact that the beds from which they have been carved are horizontal makes it difficult to prove that the plane surface is the result of planation rather than of structure.

That the Sherman peneplain in the typical locality is of later age than the mid-Tertiary formations is indicated by the fact that it passes directly across the embayments of Tertiary sediments along the east side of the arch. If the tops of the plateaus farther east are a part of the same plain, as seems probable, we have additional evidence in the fact that there also the Tertiary beds are truncated by this surface. There is, therefore, basis for the opinion that the age of this peneplain is late Tertiary, or more exactly that it has been made since the middle of the Miocene epoch. What connection the Sherman peneplain may have with the Eocene surface is very difficult to determine. It is probable that the Sherman plain truncates the older surface over the Sherman arch, while eastward the relation is reversed, and the Sherman plain lies high above the buried Eocene surface.

Passing to the east side of the Medicine Bow plateau, we again meet some features suggestive of the topography of the Laramie uplift. On the slopes of Jelm Mountain flat spurs are cut upon highly inclined schists at a level nearly 1,000 feet below the plateau surface. These seem to correspond roughly with the flat top of Red Mountain and, farther east, with the plateau surface of Boulder Ridge. If the Sherman pene-

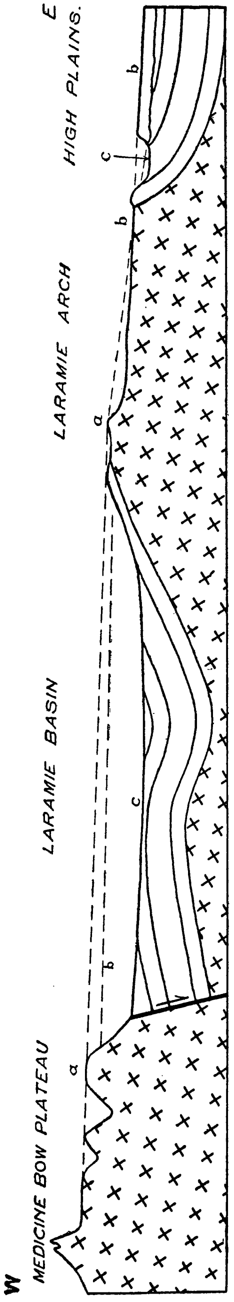

FIG. 5.—Section showing supposed relation of the Tertiary erosion surfaces to the present topography, in the latitude of Laramie. (*a*, Medicine Bow surface; *b*, Sherman surface; *c*, Leslie valleys.)

plain is represented in this part of the district these features may well be outliers of it. The topography on the west and south sides of the Laramie basin thus seems to correspond fairly well with that on the east, suggesting a common physiographic history for the several parts of the district.

In the Laramie basin itself I have not been able to recognize any remnants of the Sherman or older surfaces, and in explanation of this I suggest on a later page that the basin has been excavated in the Sherman plain.

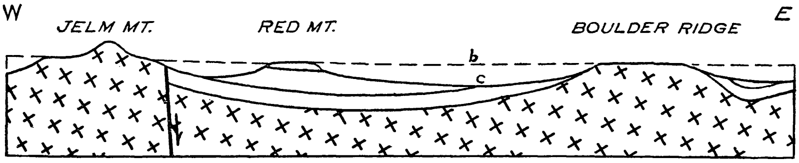

FIG. 6.—Section showing supposed relation of the Sherman surface to the present topography, near the south end of the Laramie syncline.

The Leslie cycle.—As described above, the Sherman peneplain is represented by a series of flat divides between the valleys which cross the Sherman uplift. A study of these valleys on the topographic map shows at once that their upper reaches are very different from the lower. On the eastern flank of the uplift the streams run in narrow canyons of considerable depth. Near their heads, however, the valleys are conspicuously open, broad, and flat-bottomed. The creeks meander considerably, and are bordered by broad meadows. These portions of the valleys are occupied by ranches, the meadows furnishing the hay for winter feed, while the cattle are pastured on the grassy divides between. The mining village of Leslie is situated in such a valley. Since there is no difference in the rocks, there can be little question but that the two divisions of these valleys represent two distinct cycles of erosion. The head of the valley is the older portion, while the canyon is the result of more recent rejuvenation.

It has been suggested that the Leslie valleys are not later in age than the Sherman peneplain, but that they are merely shallow open valleys in a very advanced age, and that the flat spurs between them are the subdued divides of the same cycle. I find it hard to reconcile this idea with the existence of flat plateaus east of the Sherman uplift. Their sides are relatively steep, and the valleys ascribed to the Leslie cycle are rather sharply sunk beneath them. Such a hypothesis should have consideration in future study of the district, but the weight of evidence seems to me favorable to the view that the Leslie valleys have actually been excavated in a surface which was even less rough—the Sherman peneplain. If the latter hypothesis is correct, then we have evidence of a cycle of erosion initiated by the rejuvenation of the streams after the completion of the Sherman peneplain.

This change in the activity of the streams may have been produced by actual uplift, or by a climatic variation. The sediments corresponding to these erosion cycles have not been recognized, and it is therefore difficult to get any data bearing on the climatic changes. Uplifts are known to have occurred at intervals during the Tertiary and Quaternary periods, and the occurrence of one in this district is not improbable.

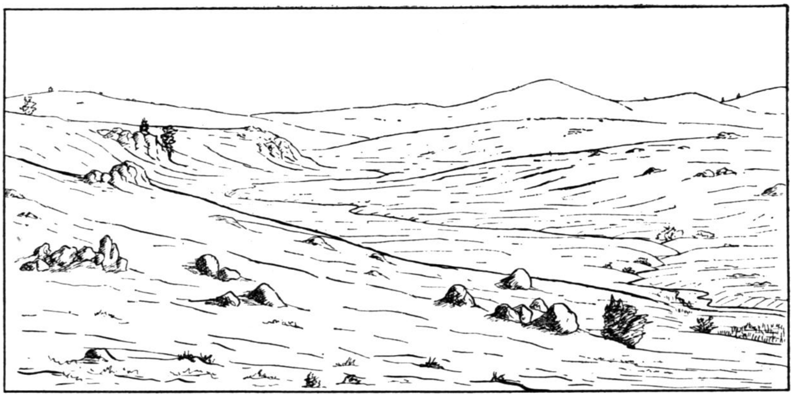

FIG. 7.—Sketch (from a photograph) of a flat-bottomed open valley (Leslie stage) near the crest of the Laramie range.

East of the uplift again we find broad flat-bottomed valleys sunk beneath the plateau surface which has been interpreted as the Sherman plain, but themselves trenched by canyons which are obviously younger. The largest of these broad depressions has been excavated parallel to the Sherman arch east of the limestone hog-backs, apparently because the soft Brule clay is exposed there. In the building of the

Colorado and Southern Railroad advantage has been taken of this depression. The bottoms of these saddles now lie from one to three hundred feet above the present creeks. They have no very clear relation to the present stream courses. While it has not been possible to trace these valleys directly into the open head-water courses which represent the Leslie cycle in the type locality, both have the same general relation to the upper or Sherman surface and to the modern canyons.

As stated above, the Laramie basin seems best explained as a depression excavated in the Sherman peneplain. In this connection I have considered the possibility that the basin is a modified downwarp between two upwarps or horsts; but this view seems to necessitate a series of remarkable coincidences by which several small upwarps affected only the somewhat irregular areas of resistant rocks and not the softer strata now exposed in the basin. On the other hand the present conditions are such as would be produced by the deeper excavation of a plain in which both hard and soft rocks are exposed. Rejuvenation readily explains this excavation. The soft Mesozoic beds were rapidly cleaned out of the Laramie syncline while the hard Paleozoic limestones and pre-Cambrian rocks were left in relief. If running water was the agent of denudation, the downward cutting was checked at the level of stream-grade and then planation at a slowly subsiding level ensued. If wind has been the dominating agent, then these nice adjustments are unnecessary. There is clear evidence that both processes are in operation, and since the Laramie river is perennial the water erosion probably dominates.

On first consideration one may experience some difficulty in explaining on this hypothesis the steep slope by which the Laramie basin is separated from the mountainous region on the west. Sheep Mountain and Jelm Mountain rise abruptly out of the plain. Both are partially flanked by faults, but the faults appear to be of ancient date (Cretaceous-Eocene) like those elsewhere in the district, for they have no topographic expression where they run out into the sedimentary rocks. From this fact it appears improbable that they are recent scarps. The faults have brought the soft Cretaceous shales squarely in contact with the much harder pre-Cambrian rocks—in the case of Sheep Mountain, a firm granite. The weaker strata must have been rapidly stripped from the granite wall, while only insignificant ravines were being cut in the face of that wall. Furthermore, where there are no faults, as around the hills southeast of Jelm Mountain, the pre-Cambrian rocks rise equally abruptly out of soft sandstones and shales. The massive limestone formation, which on the east side of the Sherman arch gives the sharp hog-back ridges, is replaced in the space of less than forty miles by an entirely different series, in which there are no very resistant members. The absence of the hog-backs is thus explained.

The highest surfaces of the broad Laramie plain are certain mesas, well represented by the rim of the Great Hollow. The tops of these mesas descend very gently from an elevation of 500 feet above the river, near the mountains, to about 100 feet above it, near the city of Laramie. At first glance they might be mistaken for outliers carved from a plain of alluvial aggradation, for the surface is very even and rock exposures are rarely visible at any distance. When carefully examined, however, it is found that inclined strata, chiefly of Mesozoic age, are exposed in many places throughout the plain; and, although they are covered by a layer of gravel, sand, and loam, this covering is never deep. Near the mountains on the west the sheet of alluvium, only a few feet in thickness, consists of coarse gravel, which is gradually replaced farther outward and down-stream by finer and finer materials. The deposits are such as are left by shifting streams, graded only for coarse material, which slowly reduce the level of their basins, while at the same time they widen them much more rapidly. The Laramie basin then is not a filled basin, but a cut plain; and the Laramie River is at present engaged in continuing the planation at a slightly lower level.

In the Laramie basin one finds no distinction between open valley heads and canyons below. All is open. I interpret this to mean that the Leslie cycle still reigns in that part of the district, the wave of rejuvenation, whatever its cause, not having worked up the Laramie River far enough to be felt within the basin.

The Hecla cycle of canyon-making.—Reference has already been made to the canyons which are sunk beneath the broad valleys of the Leslie cycle. As the open valleys in the Sherman uplift are traced eastward, they become narrower and are walled in by precipitous cliffs. The gradients of the streams are so steepened that bowldery rapids replace the grass-grown channels characteristic of the Leslie stage. Some of these canyons are three to four hundred feet deep and wholly impassable except for one on foot. Although cut chiefly in granite, they are apt to be narrowest where they pass through the upturned Carboniferous limestone. As would be expected, these younger valleys have been considerably widened in the soft Tertiary strata farther east. There again flat bottoms have been developed, and ranches are scattered along the streams. The sides of the valleys are steep, however, and tributaries coming in from the abandoned upper reaches, which I have interpreted as belonging to the Leslie cycle, descend the slopes abruptly.

In the Laramie basin we find no trace of the canyon cycle. I have suggested that the backward cutting of the canyons from the lower course of the Laramie River has not yet progressed as far as the Laramie basin. If this view is correct, the Laramie basin is still in the Leslie cycle, and its rivers have suffered no marked disturbance for a peiod of time sufficiently long to enable them to plane off broad flat valleys. Rejuvenation such as is indicated by the canyons has ordinarily been ascribed to diastrophic disturbances. More recently Johnson[1], Davis,[2] and others have emphasized the competence of climatic changes to produce the same results. In this particular case the cause has not been worked out. It can probably be done best by a broad study of the whole of the Great Plains and eastern Rocky Mountain region.

As to the age of the canyon cycle some inferences may be made. Assuming that the Sherman peneplain is post-Miocene, a considerable length of time must be allowed in addition for the excavation of the open Leslie valleys, unless these are to be correlated with the Sherman cycle itself. On this line of estimation the canyons should be no older than Pliocene. Approached from the other direction, it may be said that the canyons represent a very youthful stage of the present cycle of erosion. In other parts of the West it is known that valleys of comparable development have been made since the early part of the

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[1] W. D. Johnson, "The High Plains and Their Utilization," *U. S. G. S. Ann. Rep.*, XXI, Part 4, pp. 630, 631.

[2] W. M. Davis, "Explorations in Turkestan," *Carnegie Institution Publication No. 26*, pp. 203–6.

Pleistocene period. It is probably safe then to consider these canyons as of Pleistocene age.

Absence of glaciation.—The Laramie Range was too low to generate glaciers during the Quaternary period. The evidence of this is both positive and negative. The topography is entirely such as is produced by the action of running water and wind, and the thin residual soils have been in no wise disturbed. On the other hand, there is an entire lack of glacial drift in the district. The same is true of the greater part of the Medicine Bow plateau, although the highest range of these mountains—locally known as the "Snowy Range"—shows, even at a distance of forty miles, the characteristic sharp peaks and cirques produced by Alpine glaciers, and some of the tongues of ice ran far down their individual valleys. Judging from the Bighorn Range farther north, an elevation of more than ten thousand feet would have been necessary to induce glaciation in this latitude and climate.

Modification of the topography by wind.—Here, as in most parts of the dry West, the wind has been an agent of great importance. Mushroom monuments and other wind-carved forms are widely distributed. The many shallow hollows—some containing ponds—which are characteristic of the region, seem to be explainable only as the work of the wind. They appear in all sizes, from little saucer-like depressions to such features as the "Big Hollow" west of Laramie which is nine miles long and 150 feet deep. They are independent both of the kind of rock and the elevation, being found as well in the granite on the Sherman plateau as in the present flood plain of the Laramie River. These land forms, the stony flats strewn with polished bits of flint and honeycombed limestone, and many other significant things, testify to the efficiency of wind erosion in the Laramie region. The depositional phase of wind-work has not, however, impressed itself perceptibly on the topography. The abraded material has been largely exported.

Summary and conclusions.—Briefly stated, the more important points in the later history of the Laramie region, as interpreted in this paper, are these:

1. The district was completely buried beneath the horizontal beds of Cretaceous sediments.

2. About the close of that period the beds were moderately folded and locally faulted.

3. During the resulting cycle of erosion, the arches and scarps were beveled off and a moderately low hilly surface was produced.

4. Through terrestrial sedimentation in the Oligocene and Miocene epochs the Eocene surface was partially buried, although it probably remained exposed in the mountains.

5. After this, probably in Pliocene times, much of the region was reduced to a peneplain on which some notable monadnocks remained standing.

6. This was followed by rejuvenation, and the resulting cycle of erosion was long enough to permit the cutting of wide flat valleys in the arches and the excavation of the Laramie basin.

7. The most recent episode is a later rejuvenation which has caused new canyons to be cut east of the Laramie divide but not as yet in the plain west of it.

8. The region has not been glaciated, but its surface has been modified in detail and perhaps in gross by wind carving.